



ARPA-E

Batteries for Electrical Energy Storage in Transportation Project Summaries



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Project Title	Novel High Energy Density Lithium Ion Cell Designs via Innovative Manufacturing Process Modules for Cathode and Integrated Separator
Organization	Applied Materials, Inc.
Website	http://www.appliedmaterials.com/
Point of Contact	Dr. Connie Wang
Project Description	Applied Materials Inc. will lead an effort to develop ultra-high energy low cost lithium-ion batteries enabled by disruptive new manufacturing processes. This novel approach will focus on developing a high energy density porosity-graded cathode on 3D current collectors, an integrated separator, and a suite of modular manufacturing processes that have the potential to transform lithium-ion battery manufacturing technology. These high energy cathodes will be incorporated with new high capacity anodes to demonstrate prototype manufacturing of high energy lithium-ion cells with energy density greater than 400 Wh/kg and extremely low cost. If successful, this project will establish U.S. leadership in the manufacturing of high energy, low cost advanced lithium-ion battery technology for electric vehicles.



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Project Title	Semi-Solid Rechargeable Power Sources: Flexible, High Performance Storage for Vehicles at Ultra-Low Cost (<\$0.10/Wh)
Organization	Massachusetts Institute of Technology
Website	http://web.mit.edu/
Point of Contact	Dr. Yet-Ming Chiang
Project Description	Researchers at the Massachusetts Institute of Technology, in collaboration with A123 Systems and Rutgers University, will seek to develop a revolutionary new electrical energy storage concept for transportation that combines the best attributes of rechargeable batteries and fuel cells. This technology incorporates semi-solid high energy density rechargeable, renewable and recyclable electrochemical fuel in a flow system that decouples power from stored energy. Early stage results suggest that high energy density and system costs less than \$100/kWh can be obtained, which would enable rapid widespread adoption of electric vehicles.



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Project Title	High Performance Cathodes for Li-Air Batteries
Organization	Missouri University of Science and Technology
Website	http://www.mst.edu/
Point of Contact	Dr. Yangchuan Xing
Project Description	Researchers at the Missouri University of Science and Technology will lead a multi-disciplinary team to develop a disruptive new high energy air cathode to enable the successful development of ultra-high energy Lithium-Air batteries. Lithium-Air batteries have extremely high theoretical energy densities (5,000-12,000 Wh/kg) approaching those of gasoline due to the use of a high capacity lithium anode and oxygen from the air. However, existing Lithium-Air technologies have exhibited very low power, round trip efficiency, and cycle life due to severe performance limitations at the air cathode. In this project, researchers will seek to dramatically improve Lithium-Air air cathode performance through the development of a new hierarchical electrode structure to enhance oxygen diffusion from the air and novel high performance bifunctional oxygen reduction and evolution catalysts. If successful, this project will dramatically improve the state of the art in ultra high energy Lithium-Air batteries and will re-establish U.S. technology leadership in this potentially disruptive battery technology for long range all-electric vehicles.



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Project Title	Low-Cost Rechargeable Magnesium Batteries with High Energy Density
Organization	Pellion Technologies, Inc.
Point of Contact	Prof. Gerbrand Ceder
Project Description	<p>Pellion Technologies Inc., an MIT spin-out company, will develop inexpensive high-energy-density rechargeable magnesium-ion batteries with the potential to disrupt current energy storage technologies for electric and hybrid-electric vehicles. To develop a game-changing magnesium-ion battery, Pellion will leverage high throughput computational materials design coupled with accelerated materials synthesis and electrolyte optimization to identify new high-energy-density magnesium cathode materials and compatible electrolyte chemistries. If successful, this project will develop the first commercial magnesium-ion battery and will establish U.S. technology leadership in this exciting new high energy battery chemistry for electrified vehicle applications.</p>



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Project Title	Solid-State All Inorganic Rechargeable Lithium Batteries
Organization	Planar Energy
Website	http://www.planarenergy.com/
Point of Contact	Dr. Isaiah Oladeji
Project Description	Planar Energy Devices, Inc, an Orlando, FL based early stage battery technology company, will seek to develop an ultra high energy, long cycle life all solid-state lithium battery that can manufactured using low cost non-vacuum fabrication techniques, targeting energy densities of 400Wh/kg and 1,080Wh/liter; system costs of \$200/kWh, and cycle life of 5,000, Planar Energy Devices will demonstrate pilot manufacturing of these disruptive new batteries using a low cost roll-to-roll process in ambient environment, all inorganic materials, and solid state electrolytes whose ionic conductivity is similar to existing liquid electrolytes. If successful, this project will establish the U.S. as a leader in advanced high energy battery technology and low cost manufacturing processes in batteries for electrified vehicles.



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Project Title	Development Of Ultra-high Specific Energy Rechargeable Lithium/Air Batteries Based On Protected Lithium Metal Electrodes
Organization	PolyPlus Battery Company
Website	http://www.polyplus.com/
Point of Contact	Dr. Steven Visco
Project Description	PolyPlus Battery Company and Corning Incorporated will work together to achieve transformational improvements in rechargeable Li-Air battery technology. PolyPlus's lithium-air batteries based on proprietary protected lithium electrodes and Corning's specialization in glass, ceramics, and record of moving technology from laboratory to manufacturing have great promise for advancing Li-Air technology, which holds promise to rival the energy density of gasoline. With a clear path to commercialization this technology hopes to revolutionize Li-Air batteries for electric vehicle applications.



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Project Title	High Energy Density Capacitors
Organization	Recapping, Inc.
Point of Contact	Dr. Clive Randall
Project Description	Recapping Inc. and researchers at Pennsylvania State University will seek to develop a novel energy storage device based on a 3D nanocomposite structure with functional oxides that provide a very high effective capacitance. The basic fabrication of the dielectric materials and devices will utilize traditional multilayer ceramic fabrication methods that will provide a cost effective alternative to battery solutions, with added benefits of exploiting mechanisms that could maintain higher cycling and possibly deliver charge with high power density. This technology hopes to create a cyclable and economically competitive energy storage device that will catalyze new, related cleantech industries and contribute to the reduction of greenhouse gases and oil imports.



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Project Title	Zinc Flow Air Battery (ZFAB), the Next Generation Energy Storage for Transportation
Organization	ReVolt Technology LLC
Website	http://www.revolttechnology.com/
Point of Contact	Dr. Trygve Burchardt
Project Description	ReVolt Technology will develop a novel large format high-energy zinc-air flow battery for long all-electric range Plug-In and All Electric vehicles. This novel high energy battery concept is based upon a closed loop system in which the zinc (anode), suspended as slurry in a storage tank, is transported through reaction tubes (cathode) to facilitate the discharge and recharge of the battery. ReVolt's fundamental breakthroughs in air electrodes enable a new class of high-energy rechargeable battery systems that combines key innovations from the fields of fuel cells and batteries.



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Project Title	Development of High Energy Li-S Cells for Electric Vehicle Applications
Organization	Sion Power Corporation
Website	http://www.sionpower.com/
Point of Contact	Dr. John Affinito
Project Description	<p>Sion Power Corporation, a Brookhaven National Laboratory spin-out company, will develop an ultra-high energy Lithium-Sulfur battery able to power electric vehicles more than 300 miles between charges, with an energy density of 500Wh/kg that is 3x that of current Li-ion batteries. While the high energy potential of Lithium-Sulfur is well known, Sion Power's proprietary strategy, focusing on a manufacturable approach to lithium anode protection and employing six different physical barrier layers, highly differentiates Sion's approach from all other Lithium-Sulfur efforts. These strategies directly address cycle life and safety while also allowing higher energies. If successful, this project will clearly assert U.S. technology and commercialization leadership in ultra-high energy batteries for electrified vehicles.</p>



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Project Title	The All-Electron Battery: a quantum leap forward in energy storage
Organization	Stanford University
Website	http://www.stanford.edu/
Point of Contact	Prof. Fritz Prinz
Project Description	<p>In this project, researchers Stanford University will seek to develop an "All-Electron Battery", a completely new class of electrical energy storage devices for electric vehicles that has the potential to provide ultra-high energy and power densities, while enabling extremely high cycle life. The All-Electron Battery stores energy by moving electrons, rather than ions, and uses electron/hole redox instead of capacitive polarization of a double-layer. This technology uses a novel architecture that has potential for very high energy density because it decouples the two functions of capacitors: charge separation and breakdown strength. If successful, this project will develop a completely new paradigm in energy storage for electrified vehicles that could revolutionize the electric vehicle industry and establish U.S. leadership in advanced energy storage technology for electric vehicles.</p>



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